EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

10th Nuclear Science Training Course with NUCLEONICA
Institute of Nuclear Science of Ege University,
Cesme, Izmir, Turkey, 8th-10th October 2008

Nuclear data and searchable databases

Jean Galy

European Commission

Institute for Transuranium Elements

Postfach 2340, 76125 Karlsruhe, Germany

E-mail: jean.galy@ec.europa.eu

Joint Research Centre

nucleonica

Discovery of the ionizing radiations: an historical breakthrough

- Radioactivity was there before Earth was formed
- Man became aware of it only very recently, about 100 years ago, and the whole story is rather simple
- When the Universe was born a lot of radioactive nuclides were produced: only those one having long decay times have arrived to our days

Year	Discovery type	Author
1895	X-rays	W.C.Röntgen
1896	Radioactivity	H.Becquerel
1898	Radium & polonium	M. & J.Curie
1899	Ionizing power of radiation	E.Rutheford
1934	Artificial radioactivity (alfa)	I. Curie & F.Joliot
1934	Artificial radioactivity (neutron)	E.Fermi
1939	Nuclear fission	O.Hahn & F.Strassmann
1940	Transuranium elements (Pu)	G.T. Seaborg et al.
1942	Atomic pile Chicago	E.Fermi
1945	1st nuclear bomb, New Mexico	Los Alamos team

The first nuclear data evaluation

THE RADIOACTIVE CONSTANTS AS OF 1930

REPORT OF THE INTERNATIONAL RADIUM-STANDARDS COMMISSION

BY M. CURIE, A. DEBIERNE, A. S. EVE, H. GEIGER, O. HAHN, S. C. LIND, ST. MEYER, E. RUTHERFORD, AND E. SCHWEIDLER

I. INTRODUCTION

FOLLOWING the reorganization of the International Union of Chemistry and of the International Atomic Weights Commission, the need has arisen for the publication of special Tables of the Radioactive Constants.

This responsibility has been assumed by the International Radium Standards Commission chosen in Brussels in 1910, which has expressed its willingness to cooperate with the International Union.

Besides the members, M. Curie, A. Debierne, A. S. Eve, H. Geiger, O. Hahn, S. C. Lind, St. Meyer, E. Rutherford, E. Schweidler, the following have taken part as experts: J. Chadwick, I. Joliot-Curie, K. W. F. Kohlrausch, A. F. Kovarik, L. W. McKeehan, L. Meitner and H. Schlundt, to whom it is desired to express especial obligations.

The following report will be simultaneously published* also in the Physikalische Zeitschrift, in the Journal of the American Chemical Society, Philosophical Magazine, and Journal de Physique et le Radium.

II. GENERAL REMARKS ON SYMBOLS AND TERMS

The symbols are provisionally retained as used in the texts of St. Meyer and E. Schweidler, F. Kohlrausch and E. Rutherford, J. Chadwick and C. D Ellis as well as in the Phys. Zeits. **19**, 30 (1918), Zeits. f. Elektrochemie **24**, 36 (1918), Jahrb. d. Rad. u. Elektr. **19**, 344 (1923).

For the three radioactive gases the use of the terms radon (Rn), thoron (Tn), and actinon (An) is recommended (Zeits. f. anorg. Chem. **103**, 79, 1918), and as general term for elements of atomic number 86 the retention of the word "emanations" (Em) for the three isotopes. The words "emanate," "emanating power," etc., are retained.

The designation "radio-lead" is restricted to the natural radio-active mixture of lead isotopes in minerals and is not used to designate RaD.

RaG, ThD and AcD will be called uranium-lead, thorium-lead and actinium-lead respectively. The mixture of RaG and AcD also will be designated uranium-lead.

Instead of the designation "isotopic weight" (*poids isotopique*) as used in the earlier *Tables internationales des éléments radioactifs* for the whole-numbered atomic weights or the number of hydrogen nuclei, the term "proton number" is proposed.

* To facilitate desirable changes and additions in subsequent years it is requested that data, notes and suggestions be sent to Prof. Dr. Stefan Meyer, Institut für Radiumforschung, Boltzmanngasse 3, IX Vienna, Austria

427

75 years ago…

THE RADIOACTIVE CONSTANTS AS OF 1930

REPORT OF THE INTERNATIONAL RADIUM-STANDARDS COMMISSION

BY M. CURIE, A. DEBIERNE, A. S. EVE, H. GEIGER, O. HAHN, S. C. LIND, ST. MEYER, E. RUTHERFORD, AND E. SCHWEIDLER

with contribution from renowned scientists!

Besides the members, M. Curie, A. Debierne, A. S. Eve, H. Geiger, O. Hahn, S. C. Lind, St. Meyer, E. Rutherford, E. Schweidler, the following have taken part as experts: **J. Chadwick, I. Joliot-Curie, K. W. F. Kohlrausch, A. F. Kovarik, L. W. McKeehan, L. Meitner and H. Schlundt**, to whom it is desired to express especial obligations.

Sources of Data: from paper to WEB

Nuclear data

- Nucleus properties (half-life, mass, spin, parity, binding energy, etc.)
- Decay properties (mode of decay, branchings, associated radiations)
- Cross-sections
- Fission yields
- Energy/angle distribution
- *Radiotoxicity*
- *Derived data (e.g. isotopic power, specific activity , etc.)*

Au198	
2.3 d	2.69 d

Reference Data

79 Gold

Actual Chart: Karlsruhe

Element: Au   Mass: 198

Datasheet | Description | Derived Data | Average Cross Sections | Radiations | Prompt Gamma | Select Print Outputs

» Reference Data Notes

Density	19.3 g/cm^3		
Mass Excess	-29582.104 (± 596) keV		
Atomic Mass	197.968242303 (± 639) u		
Half-life	2.6943 (± 8) d		
Spin	2 ħ		
Parity	-		
Binding Energy	7.908573 MeV/nucleon		
Abundance	-		
Effective Dose Coefficient Inhalation	8.6E-10 (Sv/Bq)		
Effective Dose Coefficient Ingestion	1E-09 (Sv/Bq)		
Mean Decay Energies			
Alpha	0 (Mev)		
Electron	326.242 (keV)		
Photon	402.844 (keV)		
Type of decay	**Branching Ratio**	**Decay Energy,Q**	**Daughters**
ß-	1	1.3725 (MeV)	80 Hg 198

Au198	
2.3 d	2.69 d

Reference Data

79 Gold

Actual Chart: Karlsruhe

Element: Au Mass: 198

Datasheet | Description | Derived Data | Average Cross Sections | Radiations | Prompt Gamma | Select Print Outputs

Nucleonica

☑ Gamma Rays ☑ Beta Rays ☐ Discrete Electrons ☐ X-rays and Annihilation Radiation

Update

Gamma Rays

Number of lines: 3
Sum E.P (eV per disintegration): 4.01E+05

Energy, E(keV)	Δ E (keV)	Emission Probability, E.P.	Δ E.P.	Energy x Emission Propability (keV)
411.802	0.00017	0.9556	0.0007	3.94E+02
675.884	0.0007	0.00804	9E-05	5.43E+00
1087.68	0.0007	0.0016	6E-05	1.74E+00

Download ◉ Excel ○ CSV Separator: Semicolon (";") ☑ Use field qualifier (")

Graph

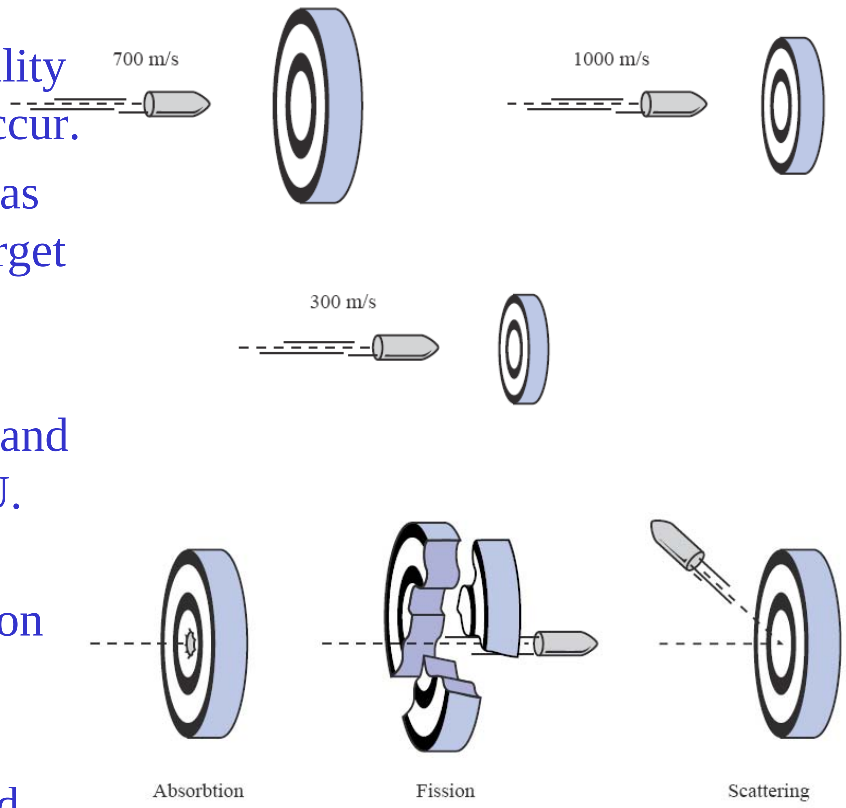
Beta Rays

Number of lines: 3
Sum E.P (eV per disintegration): 9.54E+05

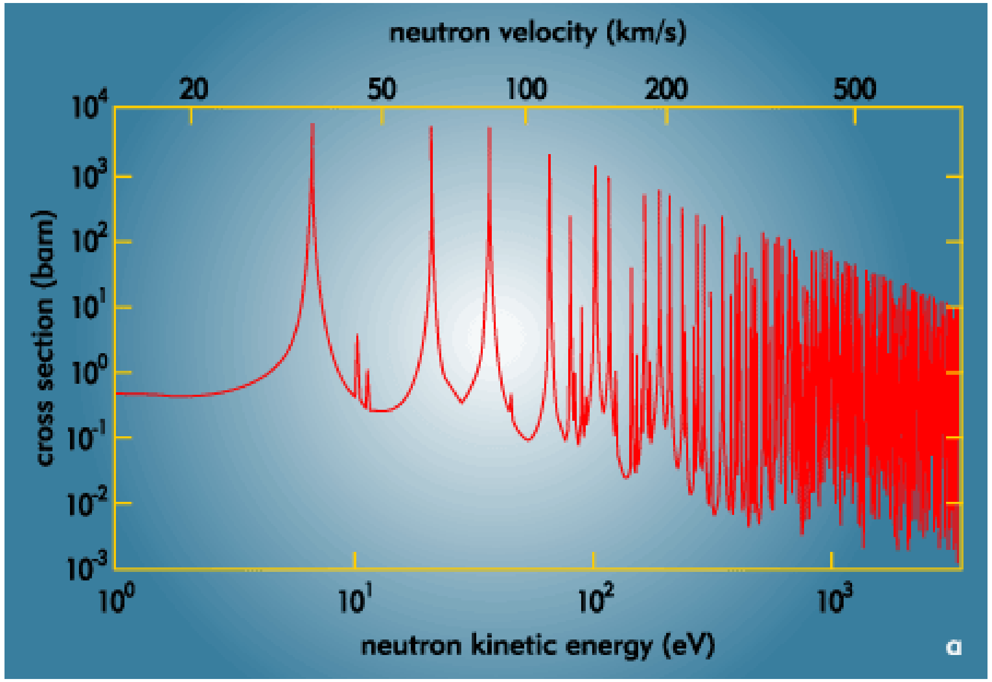
End Point, E(keV)	Δ E (keV)	Emission Probability, E.P.	Δ E.P.	Energy x Emission Propability (keV)
960.689	0.499996	0.98985	0.00015	9.51E+02
284.807	0.499996	0.0099	0.0001	2.82E+00
1372.49	0.499996	0.00025	5E-05	3.43E-01

Neutron Cross Sections (I)

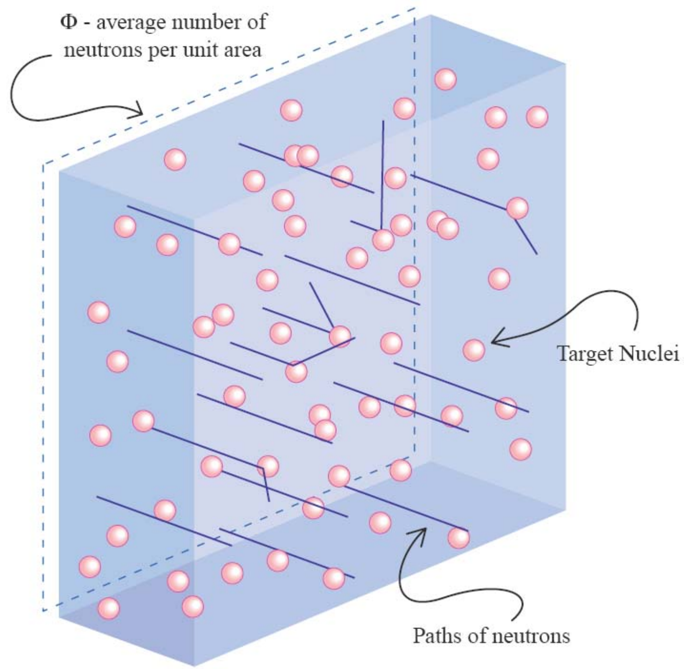
- Cross section is a measure of the probability for a reaction between two particles to occur.
- Unit of cross section is the barn, which has the dimensions of area – analogy with target size.
- Microscopic cross section defines probability of **reaction** between neutron and an individual particle or nucleus, i.e. ^{235}U.
- Macroscopic cross section defines probability of **interaction** between neutron and some bulk material, i.e. concrete
- Three most common types of reaction cross sections are **absorption**, **fission** and **scattering**.



Neutron Cross Sections (II)



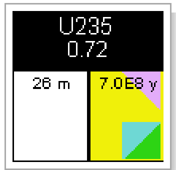
^{238}U Capture Cross Section, CEA



$$\text{neutron reaction rate} = N\Phi\sigma_{ave}$$

- Macroscopic cross section is related to mean free path (λ).
- λ is the average path length in material between two collisions.

Joint Research Centre



Reference Data

92 Uranium

Actual Chart: Karlsruhe

Element: U Mass: 235

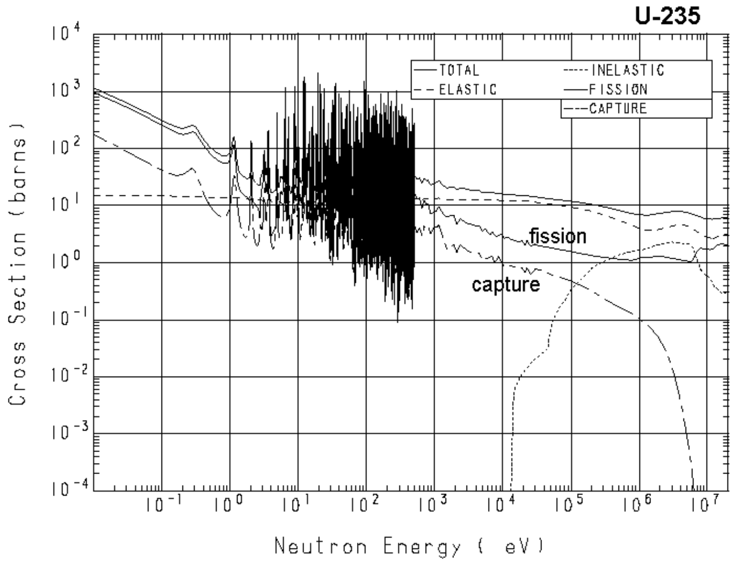
Datasheet | Description | Derived Data | Average Cross Sections | Radiations | Prompt Gamma | Select Print Outputs

Neutron Induced Reactions

Library: JEF-2.2

Reaction \ Neutron Energy	2200-m/s (Barn)	Maxwell Average (Barn)	Resonance Integral (Barn)	14-MeV (Barn)	Fission Average (Barn)
total	697.5	606.2	556.5	5.862	7.657
elastic	15.11	15.02	152.8	2.84	4.409
inelastic			0.1376	0.4177	1.917
n,2n				0.5036	0.01369
n,3n				0.03758	1.923E-05
n,g	98.95	86.32	132	0.001213	0.09519
n,fission	583.2	504.4	271.6	2.06	1.219

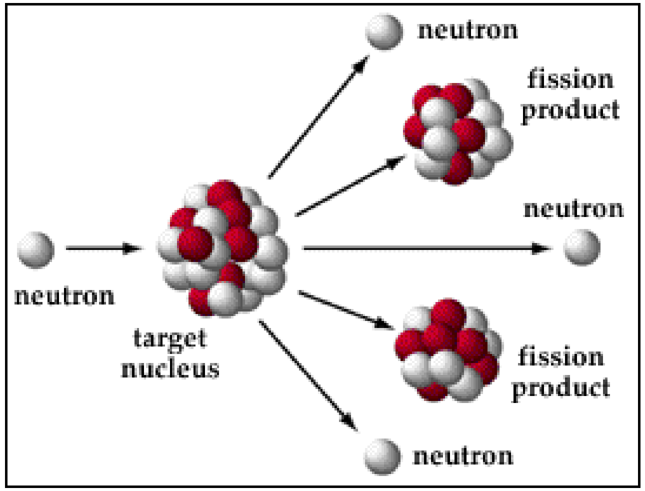
Joint Res

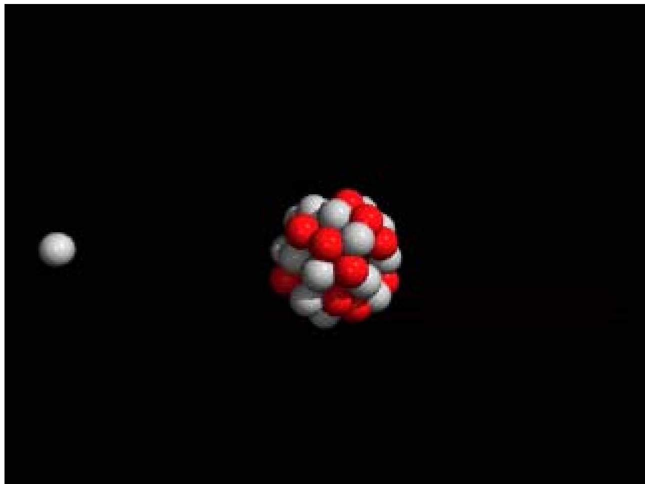


EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

Neutron Induced Fission

- Neutron transport calculations are complicated; one must resort to Monte Carlo techniques which are computationally expensive.
- A tool for analysis of neutron induced fission is included in Nucleonica: the fission yield module.
- It can be used to calculate the relative abundances of the various fission products for fissile radioisotopes.





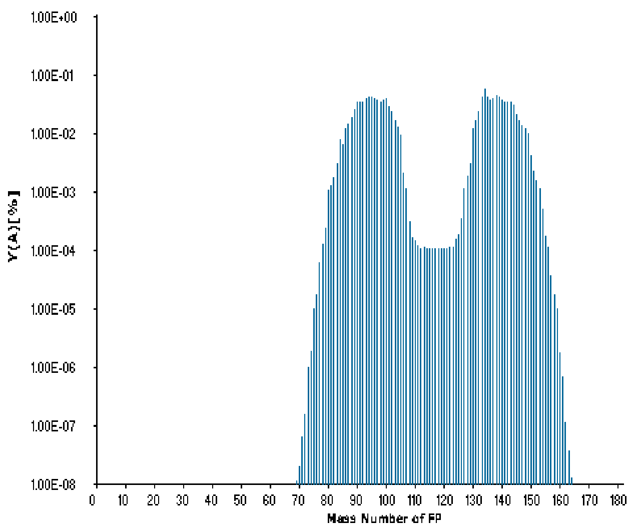
Joint Research Centre

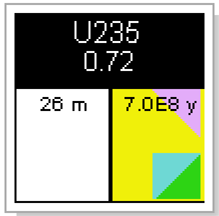
Fission Yields

- Independent yield: number of atoms of a specified nuclide produced directly (after emission of prompt neutrons but excluding radioactive decay) per fission
- Cumulative yield: number of atoms of a specific nuclide produced directly and via decay of precursors per fission
- Chain yield: number of isobars of specific mass produced per fission

Fission Products

- Isotopes of more than 30 elements are observed as fission products
- Most of the fragments are far from stability and decay by β^- or delayed neutron emission





Fission Yields

92 Uranium

Actual Chart: Karlsruhe

Element: U Mass: 235

Select | Fission Yields

Library: ENDF-BVI Type of fission: Thermal fission

Fission Yields Settings

Element: Cs

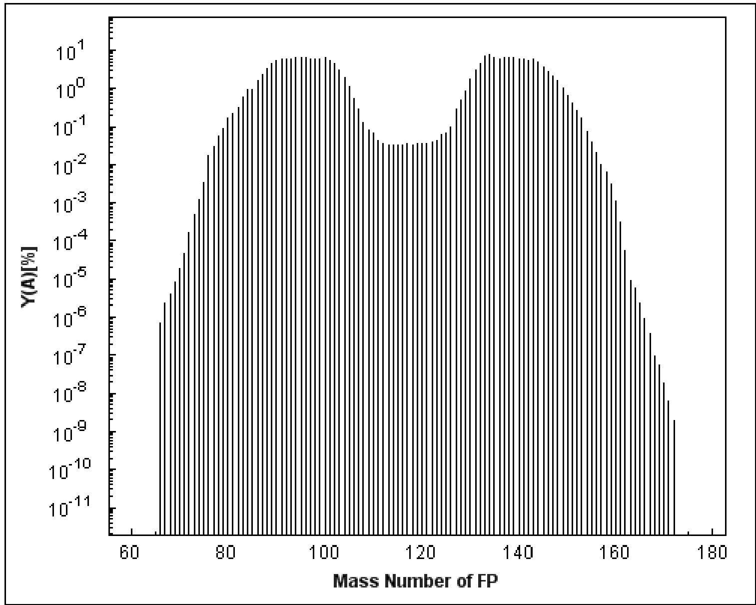
Mass Number:

Min Half-life: 25 Years

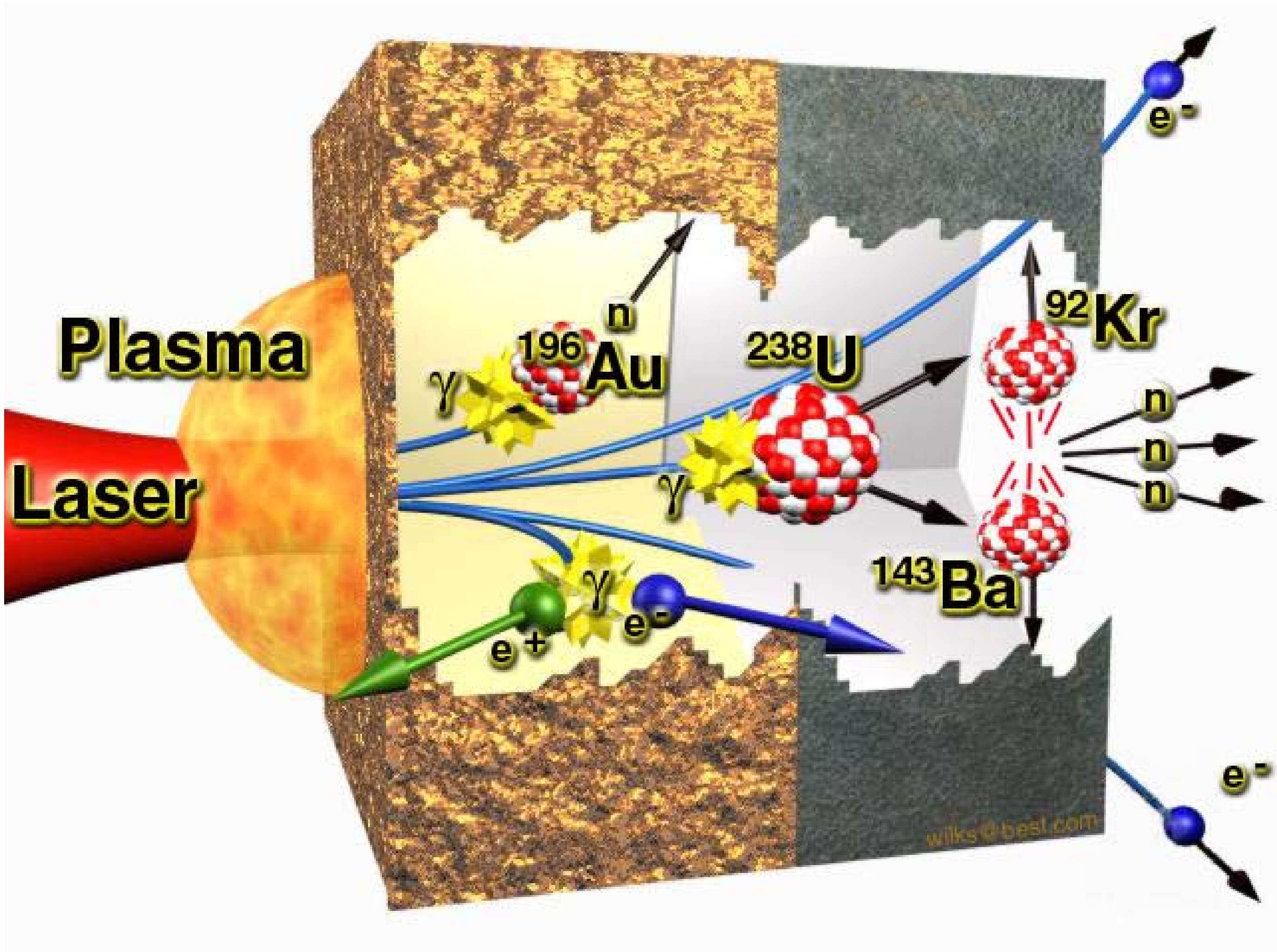
Max Half-life: 35 Years

☑ Enable advanced comparison

Results Reset

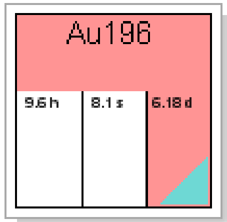


Case study: $^{197}Au(\gamma,n)^{196}Au$ investigation



Characteristic gamma lines from ^{196}Au decay

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre



Reference Data

79 Gold

Actual Chart: Karlsruhe

Element: Au   Mass: 196

Datasheet | Description | Derived Data | Average Cross Sections | Radiations | Prompt Gamma | Select Print Outputs

Nucleonica

☑ Gamma Rays ☐ Beta Rays ☐ Electron Capture and/or Positron Emission ☐ Discrete Electrons ☐ X-rays and Annihilation Radiation

Update

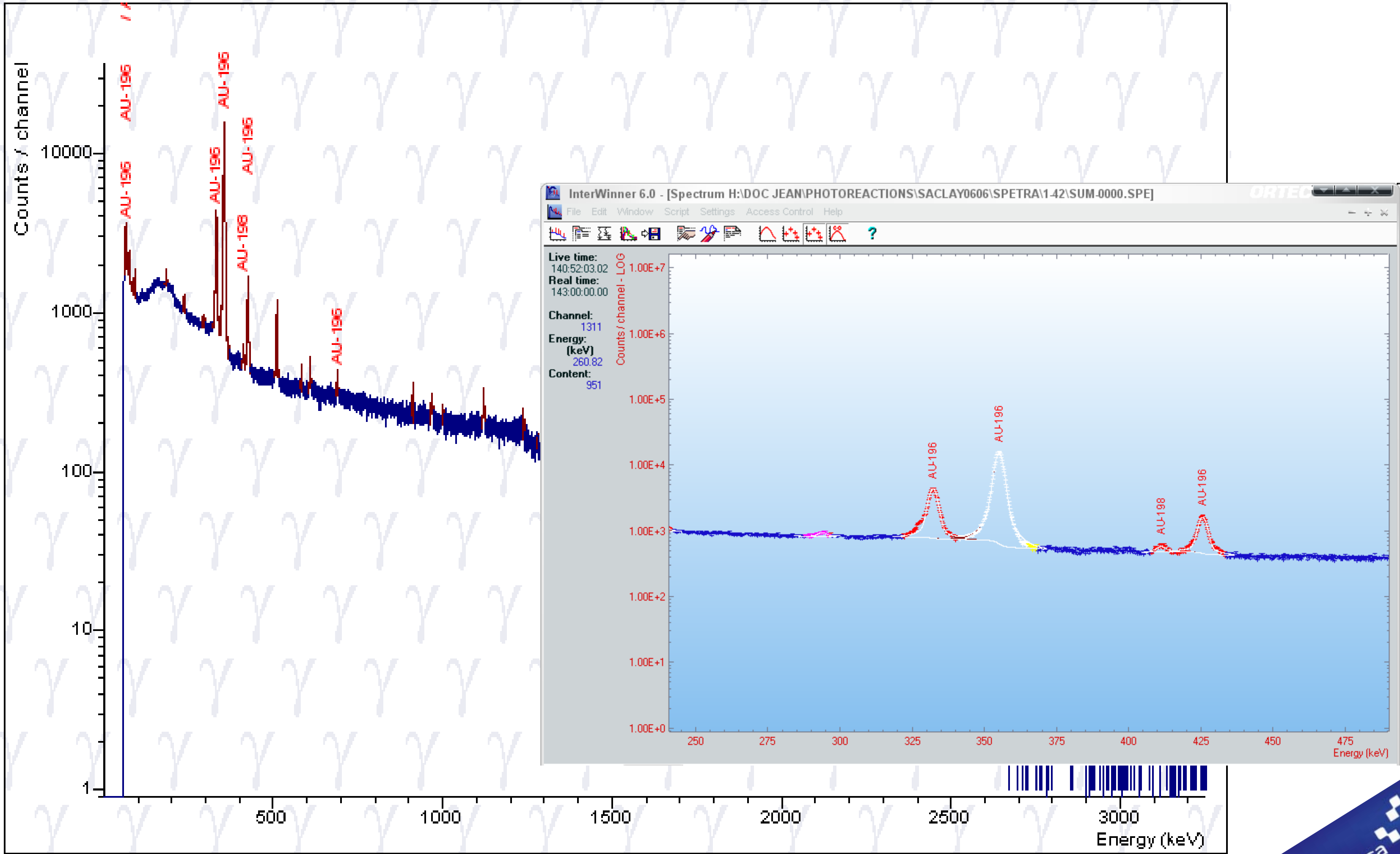
Gamma Rays

Number of lines: 16
Sum E.P (eV per disintegration): 4.19E+05

Energy, E(keV)	Δ E (keV)	Emission Probability, E.P.	Δ E.P.	Energy x Emission Propability (keV)
355.73	0.05	0.870464	0.0078792	3.10E+02
333.03	0.05	0.228932	0.00561886	7.62E+01
426.1	0.08	0.066312	0.0077364	2.83E+01
521.4	0.2	0.00389097	9.39017E-05	2.03E+00
1091.4	0.2	0.00148849	6.24043E-05	1.62E+00
326.2	0.4	0.000496164	0.000113249	1.62E-01
759.1	0.3	0.000443937	1.7867E-05	3.37E-01

European Commission
Directorate-General
Joint Research Centre

Measurement of γ-spectrum



Joint Research Centre

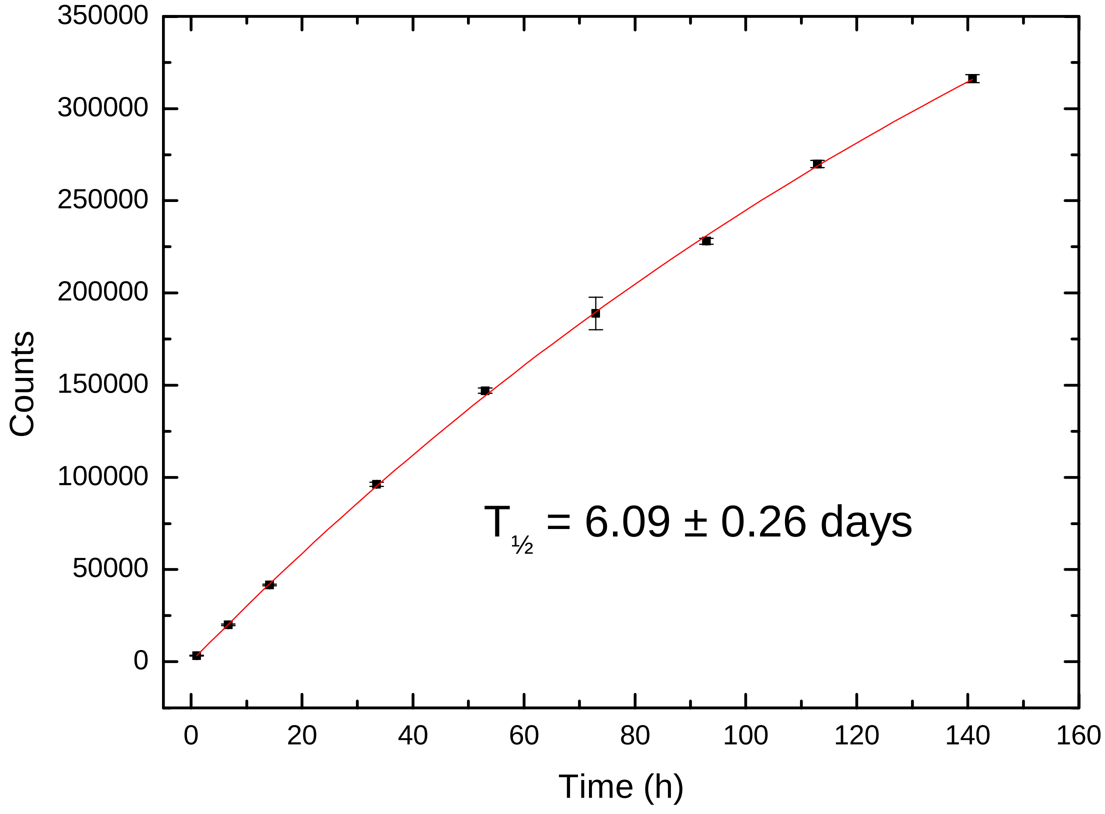
Element: Au Mass: 196

Datasheet | Description | Derived Data | Average Cross Sections | Radiations | Prompt Gamma | Select Print Outputs

» Reference Data Notes

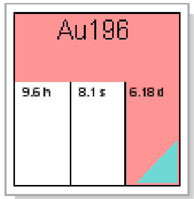
Density	19.3 g/cm^3		
Mass Excess	-31140.018 (± 2972) keV		
Atomic Mass	195.966569813 (± 3191) u		
Half-life	6.183 (± 10) d		
Spin	2 ħ		
Parity	-		
Binding Energy	7.914861 MeV/nucleon		
Abundance	-		
Mean Decay Energies			
Alpha	0 (Mev)		
Electron	27.8614 (keV)		
Photon	472.119 (keV)		
Type of decay	Branching Ratio	Decay Energy,Q	Daughters
ß+	0.928	1.5057 (MeV)	78 Pt 196
ß-	0.072	0.686 (MeV)	80 Hg 196

Half-life determination



nucleonica ... web driven nuclear science

Applications | My Preferences | Print | Help



Reference Data

79 Gold

Actual Chart: Karlsruhe

Element: Au Mass: 196

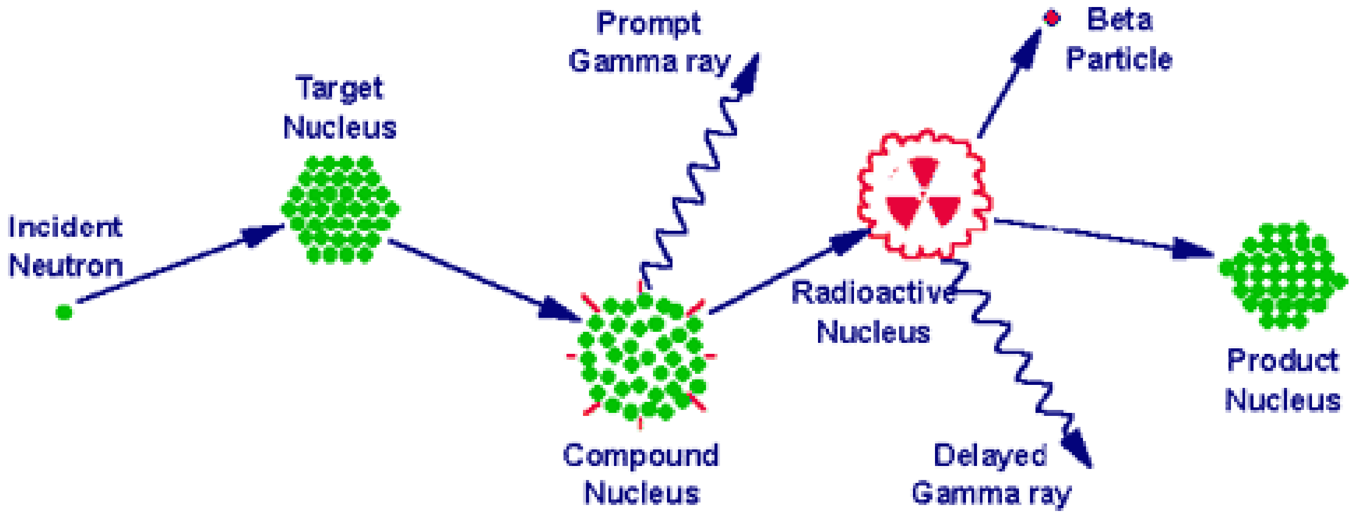
Datasheet | Description | Derived Data | Average Cross Sections | Radiations | Prompt Gamma | Select Print Outputs

	Half-life	6.1669 d 0.0006
	Average or mean lifetime	8.90E+00 d
	Specific Activity	3.99E+15 Bq/g
Heat Generation:		
	Isotopic Power (α)	0.00E+00 W/g
	Isotopic Power (α+β)	1.78E+01 W/g
	Isotopic Power (α+β+γ)	3.19E+02 W/g
Gamma Emission:		
	Specific Gamma Dose Rate at 1m.	6.15E-02 µSv/(MBq·h)
	Gamma Dose Rate Constant	6.86E-02 mSv·m²/GBq/h

Download Excel CSV Separator: Semicolon (";") Use field qualifier (")

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
Joint Research Centre

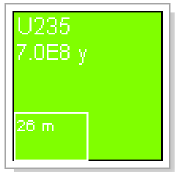
Prompt Gamma Rays / Neutron Activation Analysis



Joint Research Centre

nucleonica

Database for prompt gamma ray neutron activation analysis



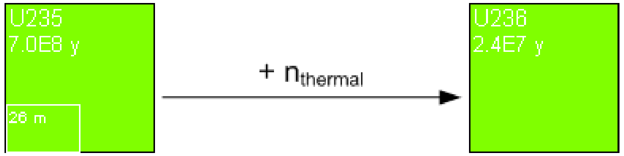
Reference Data

92 Uranium

Actual Chart: Binding Energy

Element: U Mass: 235

Datasheet | Description | Derived Data | Average Cross Sections | Radiations | Prompt Gamma | Select Print Outputs



Gamma E(keV)	Error on Gamma Energy	σ(n,γ(E)) (Barn)	Error on σ(n,γ(E))	K0	Error on K0
243.6	0.2	0.023	0.003	0.00029	3.82E-05
297	0.1	0.22	0.02	0.0028	0.000255
300	0.1	0.016	0.003	0.0002	3.82E-05
909.06	0.06	0.026	0.004	0.00033	5.09E-05
943.14	0.07	0.082	0.01	0.00104	0.000127
1014.1	1	0.026	0.004	0.00033	5.09E-05
1279.01	0.1	0.2	0.01	0.00255	0.000127
6395.16	0.15	0.0032	0.0004	4.1E-05	5.09E-06

Searchable DBs

Joint Research Centre